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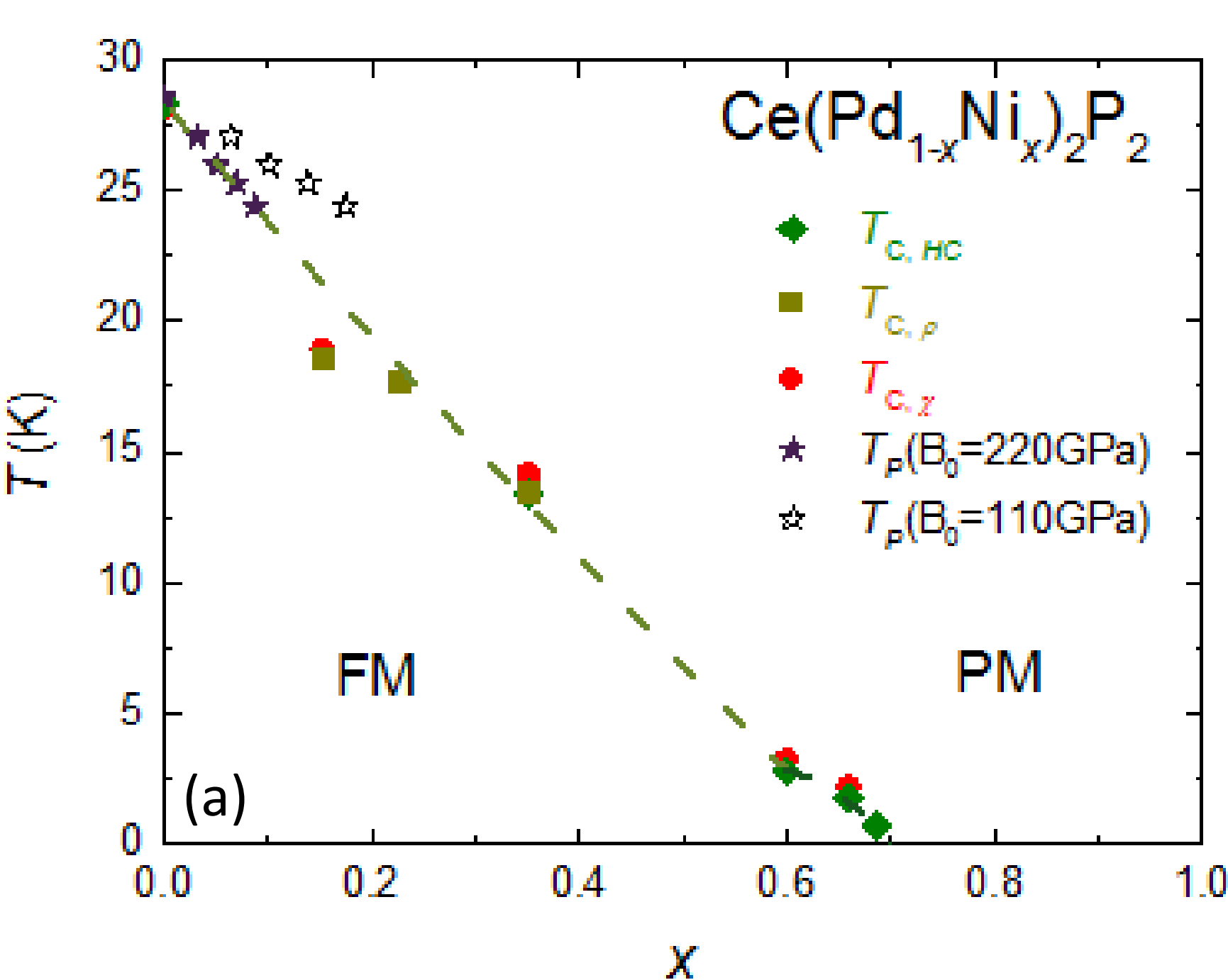
Tuning the ferromagnetic tri-critical point and quantum critical point in $\text{Ce}(\text{Pd}_{1-x}\text{Ni}_x)_2\text{P}_2$ under high magnetic fields

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Introduction

We recently uncovered a ferromagnetic quantum phase transition in the Kondo lattice alloy series $\text{Ce}(\text{Pd}_{1-x}\text{Ni}_x)_2\text{P}_2$ near $x_{\text{cr}} \approx 0.7$ (Fig. 1a). This provides the rare opportunity to study phenomena associated with ferromagnetic quantum fluctuations and to contrast them with predictions from different theories: e.g., such as those proposed by Belitz, Kirkpatrick, and Vojta (BKV) [1-5]. In particular, the BKV theory predicts that for clean systems there is a tri-critical point separating a high temperature line of second order phase transitions from a low temperature line of first order phase transitions, where the application of a magnetic field produces wing-like second order phase boundaries that intercept zero temperature (Fig. 1b). With increasing disorder (e.g., through alloying), the tri-critical point is pushed to zero temperature and the second order phase boundary extends all the way to zero temperature (Fig. 1c). This has spurred interest in ferromagnetic quantum criticality in disordered metals like $\text{Ce}(\text{Pd}_{1-x}\text{Ni}_x)_2\text{P}_2$, where a possibility is that they might host anomalous metallic states and even unconventional superconductivity. Here we report initial results from magnetoresistance and tunnel diode oscillator measurement near $x \approx x_{\text{cr}}$, to probe whether the wing-like and/or anomalous electrical transport appears in the critical region.



Y. Lai *et al.*, Phys. Rev. B **97**, 224406 (2018)

Fig. 1 (a) T - x Phase diagram: Curie temperature T_C is suppressed linearly with x , resulting in a ferromagnetic quantum phase transition near $x_{\text{cr}} = 0.7$. The main tuning parameters are unit cell volume and disorder. Near x_{cr} the Fermi liquid behavior breaks down. (b) **BKV T - P - H phase diagram for clean FM-QPT:** Universal phase diagram features 2nd order to 1st order phase boundary separated by tri-critical point. (c) **BKV T - P - H phase diagram for disordered FM-QPT:** Disorder suppresses the tri-critical point and 2nd order phase transition goes to zero temperature. [1-5]

Magnetoresistance

$\text{Ce}(\text{Pd}_{1-x}\text{Ni}_x)_2\text{P}_2$ $x = 0.83$

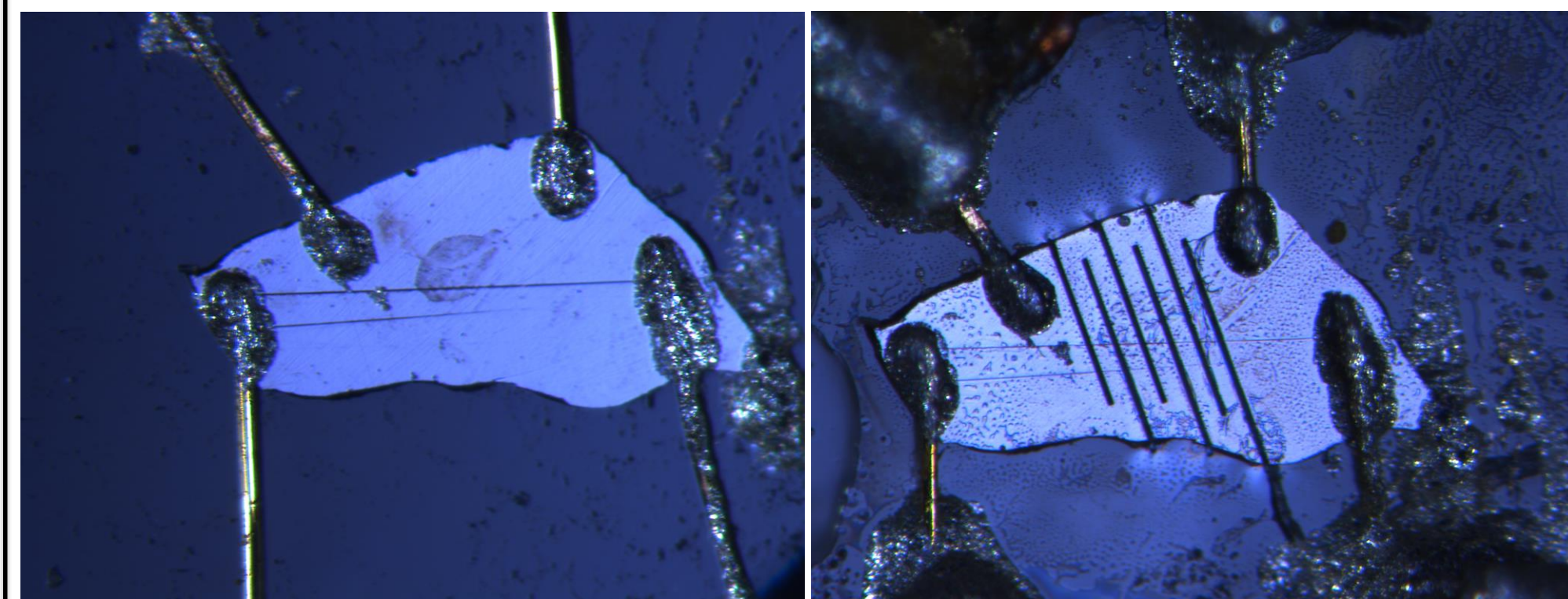


Fig. 2 Sample with Focused Ion Beam structure

For $x = 0.83$: right above the critical x -region

Electrical Resistance $R = \rho L/A$

After FIBing, R increases by an order of 10. This is important for measurements in pulsed fields because there are many noise sources from the pulsed field measurement:

- (1) Pulse magnet itself
- (2) Taking data at high frequency
- (3) Contact resistance
- (4) Vibration from the cryogen system and magnet

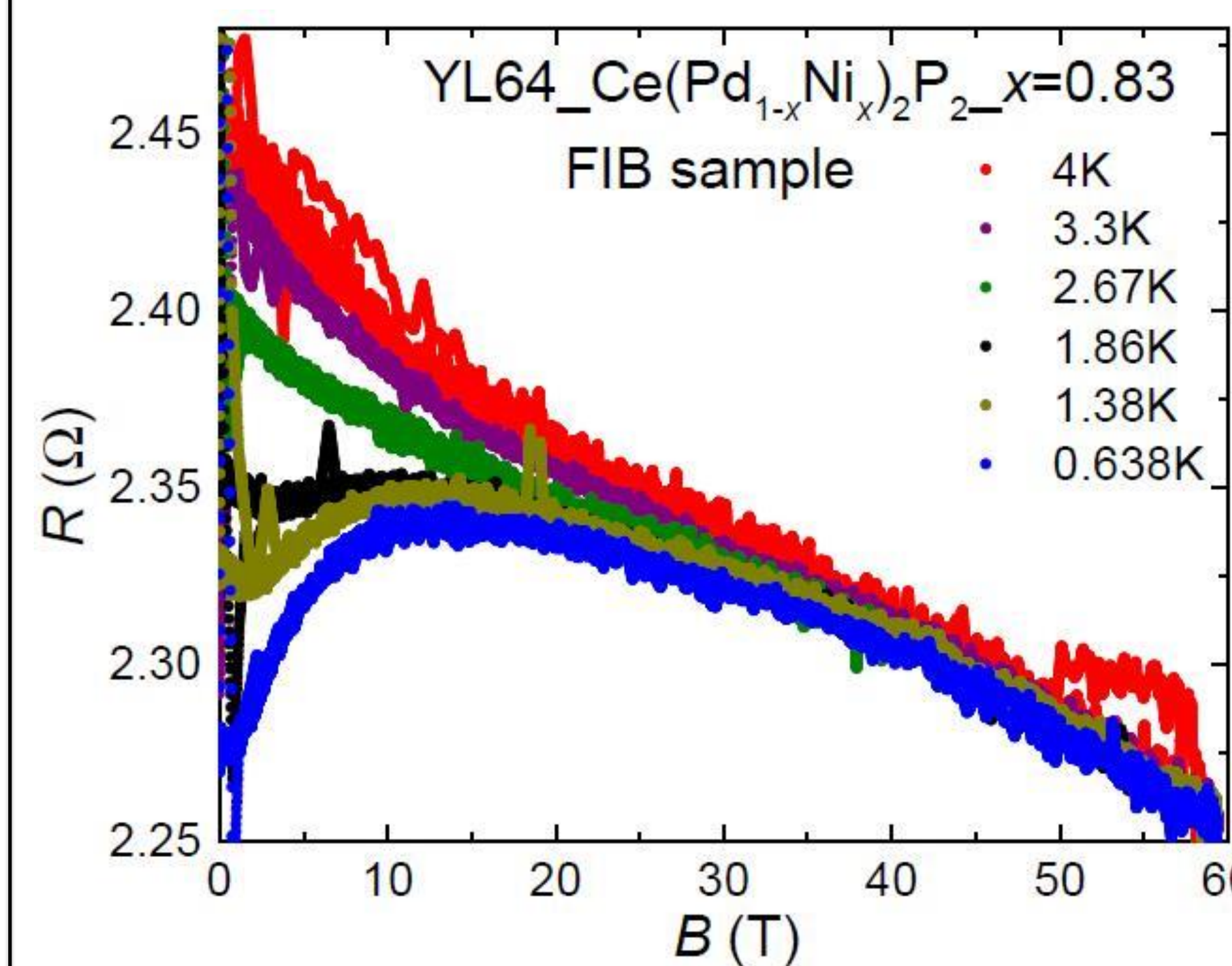


Fig.3 Magnetoresistance for $\text{Ce}(\text{Pd}_{1-x}\text{Ni}_x)_2\text{P}_2$ $x = 0.83$

- Crossover-like behavior with T and H
- No evidence for the “wing” behavior expected from clean BKV phase diagram.

Tunnel Diode Oscillator [6]

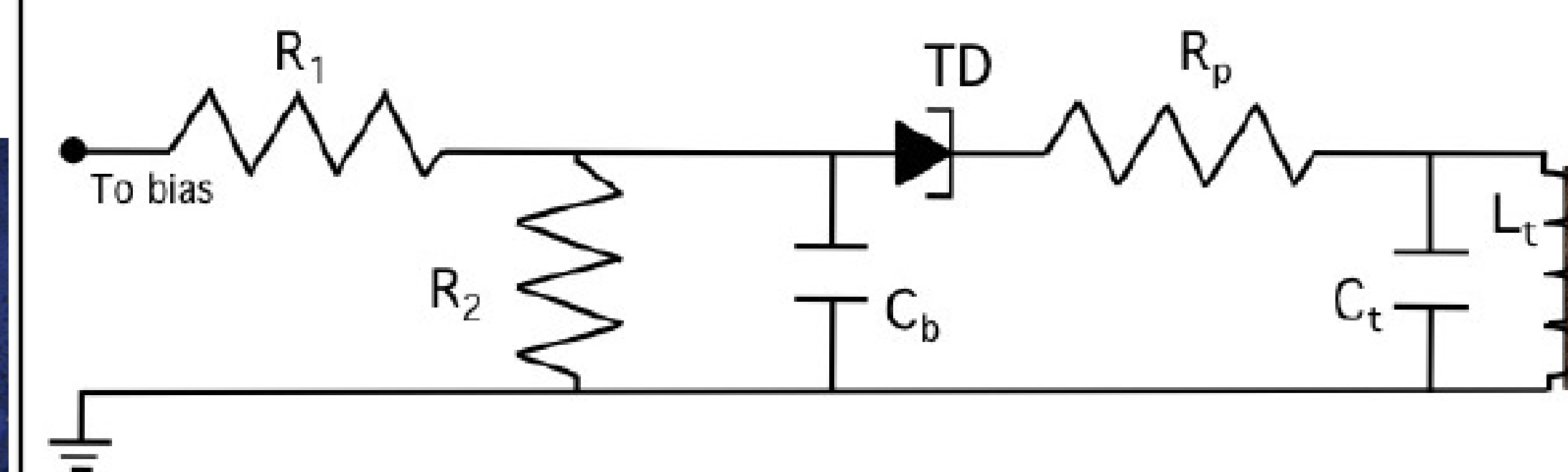


Fig. 4 TDO measurement setup

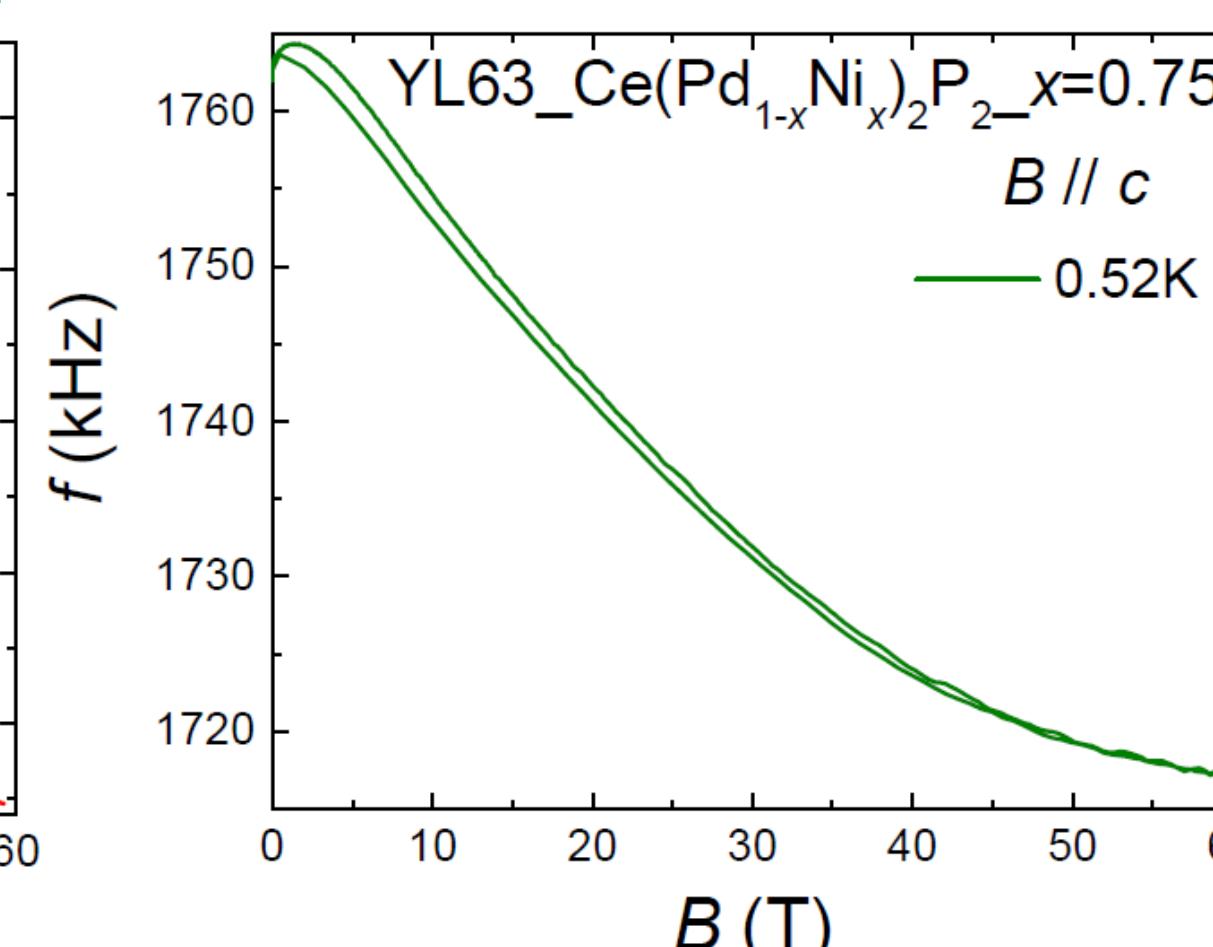
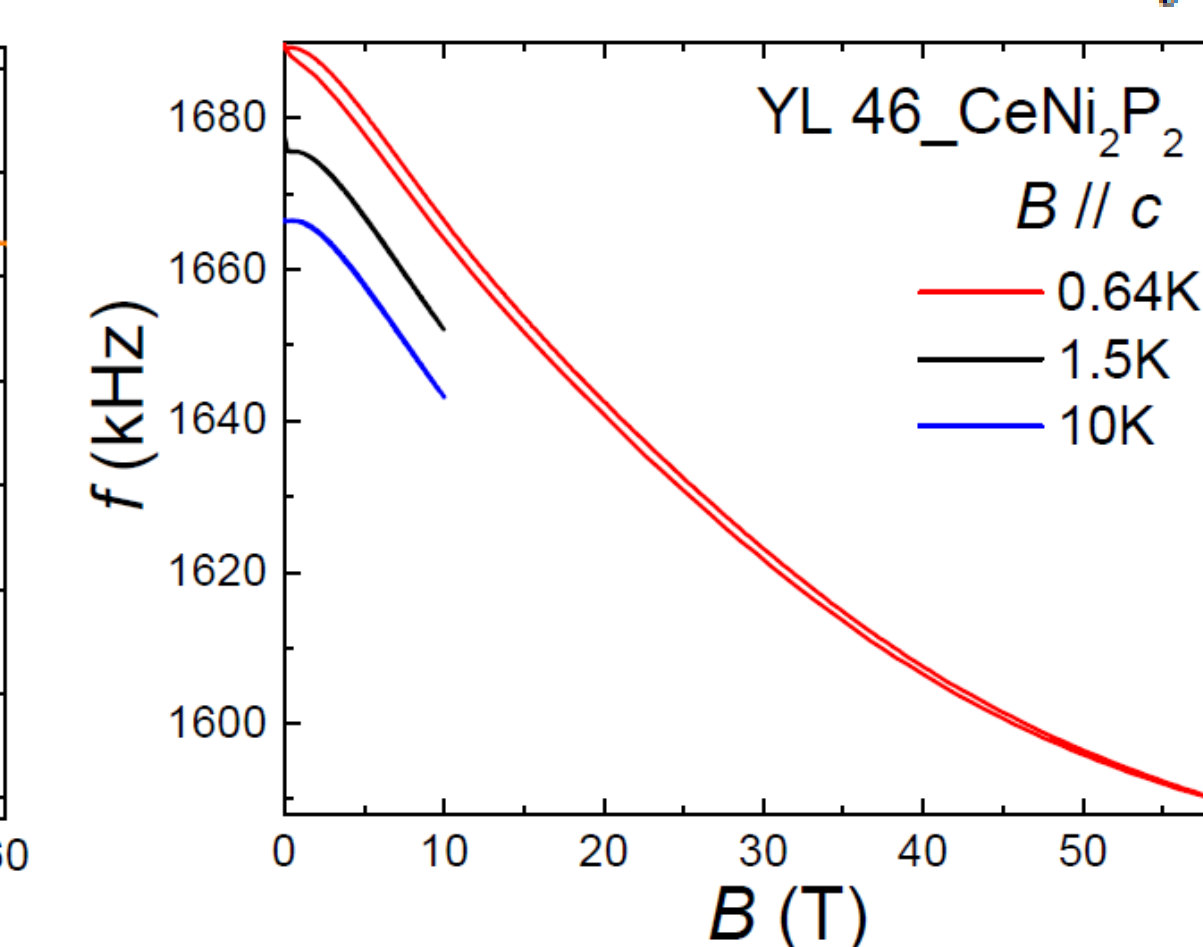
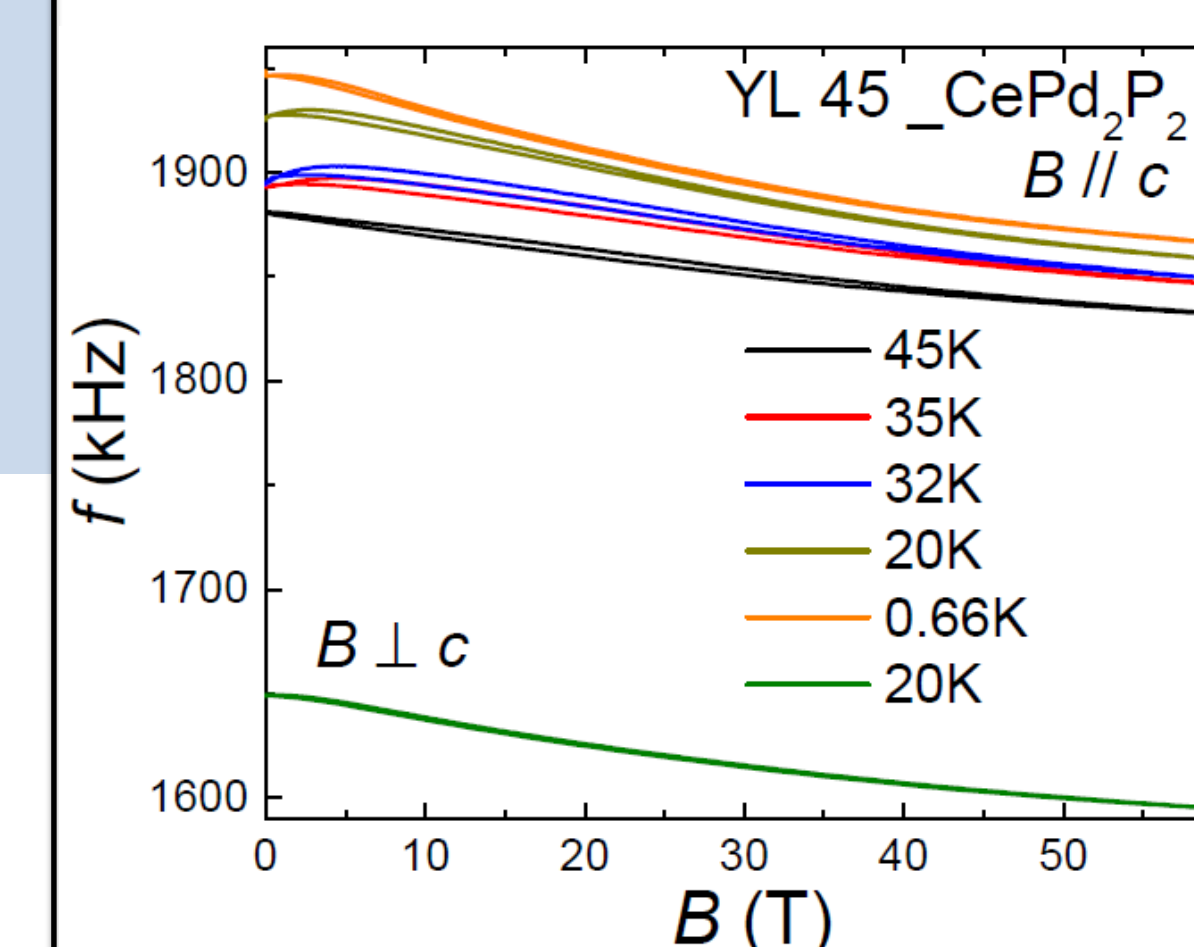


Fig.6 TDO measurement on several samples under pulsed fields

- No quantum oscillation found for CePd_2P_2 or $\text{CePd}_{2-x}\text{Ni}_x\text{P}_2$, Cleaner sample as well as lower T and larger H are needed.
- The data did not show much T dependence and there is no field induced phase transition.

Conclusions and Future work

- As predicted by BKV, if there is enough disorder the wings will not be observed
- Magnetoresistance, TDO or torque measurement on sample close to the FM-QCP are planned

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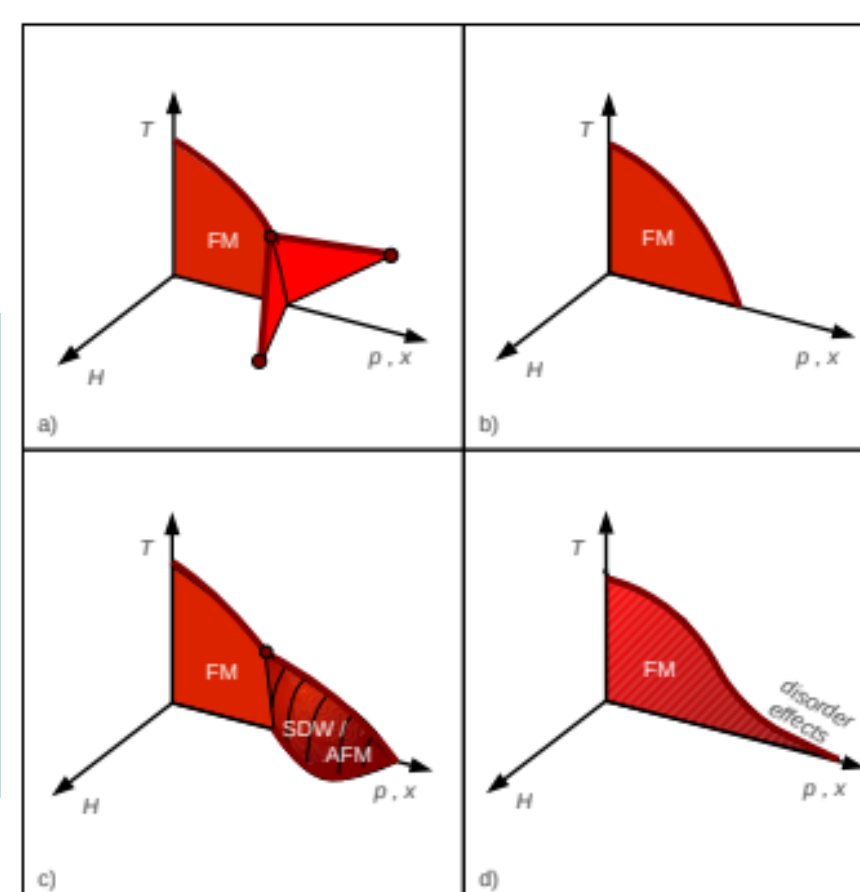


Fig. 7 Schematic phase diagrams Observed in ferromagnetic (FM) systems that show, at the lowest temperatures realized. [1]

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